Chapter 1 INTRODUCTION

1.1 The RC2000 Antenna Controller Family

The RC2000 antenna controller family consists of the RC2000A, RC2000B POLAR, RC2000B AZ/EL, RC2000C POLAR, RC2000C AZ/EL and RC2000C EL/AZ dual axis antenna controllers. All of the various models are designed to work with 36-volt actuators and pulse type position sensors.

The RC2000A is a general-purpose dual axis antenna controller without the capability to track inclined orbit satellites. The RC2000A does have the ability to be controlled via an RS-422 serial interface. An IBM PC program, referred to as AUTOPILOT, is available to control the RC2000A and Standard Agile Omni satellite receivers. An optional daughter board, designated RC2KPOL, allows the RC2000A to control a rotating feed powered by a 24 volt DC motor that employs a potentiometer for position feedback.

The RC2000B antenna controllers will track inclined orbit satellites, but do not have the ability to be controlled via the onboard RS-422 serial interface. The RC2000B POLAR antenna controller is designed to work with polar mount antennas. Two types of polar mounts are supported, elevation track and declination track. With the elevation track polar mount, the elevation (or latitude) angle adjustment is motorized. For the declination track polar mount, the mount declination angle adjustment is motorized. The RC2000B AZ/EL antenna controller is designed to work with elevation over azimuth type mounts. The RC2000B does not support the RC2KPOL daughter board.

The RC2000C controllers combine the serial communication and rotating feed support (provided by the optional RC2KPOL daughter board) capabilities of the RC2000A with the inclined orbit satellite tracking capabilities of the RC2000B. The RC2000C POLAR supports polar mounts with motorized elevation or declination adjustments. The RC2000C AZ/EL is designed to interface with antennas that employ elevation over azimuth type mounts. The RC2000C EL works with azimuth over elevation mounts.

Here is a brief listing of the capabilities of the RC2000 family of antenna controllers:

1. The controller utilizes a solid-state drive system capable of providing 8 amps to the antenna actuators. The drive system has built-in over-current sensing, with mechanical relay backup to disconnect the drive from the actuators in the event of a fault. It is possible with the RC2000 to control antennas not powered by 36 volt DC actuators. See the white paper entitled “Controlling Antennas Powered by AC or Large DC Motors with the RC1000 or RC2000 Antenna Controllers.” This paper can be obtained from our web site at: www.researchconcepts.com.

2. The controller can control polarization via a polarotor type interface. In addition, an AUTO-POL feature allows the polarization to be controlled via a digital input or contact closure supplied by a receiver to the antenna controller.

   The controller also has an internal expansion port that can accept optional daughter boards. Two daughter boards are available which can provide polarization control, designated RC2KPOL and RC2KHPP. The RC2KPOL is designed for use with the Seavey model ESR-124D motorized feed with potentiometer feedback. The Seavey feed requires 24 volts at 500 milliamps. The RC2KHPP option is designed for motorized feeds with potentiometer feedback which require 5 to 40 volts DC at currents up to 3 amps. Version 1.x0 of the RC2000A software supports the RC2KPOL option. Version 1.x1 of the RC2000A software supports the RC2KHPP option. The RC2KPOL and the RC2KHPP options are supported in only the RC2000A and RC2000C series. Contact the factory for versions of the RC2000C software that supports the RC2KHPP.

3. Position sensing feedback can be supplied by any pulse-based sensor, reed switch, Hall effect, or electro-optical. There is no need for special sensors or actuators. The RC2000 antenna controllers keep track of both rising and falling pulse edges from the pulse sensor for increased accuracy.

4. In each of the RC2000 controllers, the non-volatile memory can hold position and polarization data for numerous satellites. The RC2000A can accommodate 50 geostationary satellites. The RC2000B can accommodate 50 satellites total…5 of which may be in an inclined orbit. The RC2000C can hold data for 35 satellites total…4 of which may be in an inclined orbit.

5. The Adapti-Drive variable speed control system allows the user to specify the desired slow speed for each axis. The Adapti-Drive system will then adjust the actuator voltage (via a pulse width modulation scheme) to maintain the speed selected by the user. This alleviates the problem of poor speed regulation with varying direction along a given axis associated with constant voltage slow speed systems.

6. The RC2000A and RC2000C are equipped with an RS-422 communications port. This allows the controller to interface with a PC. The communication protocol used is compatible with the popular SA-Bus protocol. Two IBM PC compatible programs are included with the controller. The optional AUTOPILOT software package allows a single PC to control multiple antenna positioners and satellite receivers. An optional RS-232 to RS-422 interface converter, designated RC1KADP, is available to convert the RS-232 interface (which is standard on PC's) over to the RS-422 interface required for the SA-Bus protocol.

1.2 Tracking Inclined Orbit Satellites

To understand the operation of our controller, it is necessary to review the characteristics of inclined orbits. Satellites are allowed to drift into an inclined orbit to save satellite station-keeping propellant. East-West station-keeping maneuvers must be performed to keep the satellite in its assigned orbital position. North-South station-keeping is performed to keep the satellite in the earth's equatorial plane. Natural forces tend to cause the satellite's orbital plane to tilt, or become inclined to the earth's equatorial plane. By suspending North-South station-keeping maneuvers (while continuing East-West station-keeping), a significant propellant savings can result. Typically, for a geostationary satellite, 90 percent of the total propellant usage is due to North-South station-keeping maneuvers.

A satellite in an inclined orbit has certain known characteristics (to a close approximation). The inclination of the satellite's orbital plane relative to the earth's equatorial plane increases at a rate of between 0.6 and 0.9 degrees per year. The rate varies from year to year. The apparent motion of the satellite is periodic with time; the period is approximately 23 hours, 56 minutes, 4 seconds. The apparent motion of the satellite about a nominal position as viewed from the center of the earth is in a figure eight pattern, as described by the following equations:

Height of the figure eight (North-South) : 2 * i degrees
Width of the figure eight (East-West) : (i * i) / 115 degrees
where i is the inclination of the satellite's orbital plane to the earth's equatorial plane in degrees

Examination of the equations shows that the figure eight is much taller than it is wide. For example, a 5-degree inclination results in an apparent East-West position variation of 0.217 degrees. The apparent motion of the satellite is practically a straight line oriented in a North-South direction. This knowledge of the satellite's period and apparent motion is exploited by our tracking antenna controllers.

1.3 RC2000B/C Tracking Algorithm

The tracking algorithm used by the RC2000B/C antenna controllers can be divided into 3 distinct parts - STEP_TRACK, PROGRAM_TRACK, and SEARCH. The process will be described in chronological order as seen by a user initiating a track on a satellite for the first time. To initiate the track process the user jogs the antenna to the satellite and verifies the identity of the satellite. The system then enters STEP_TRACK mode.

In STEP_TRACK mode the controller periodically peaks the receiver's AGC signal strength by jogging the antenna. The time and position are recorded in a track table maintained in the controller's non-volatile memory. The interval between peakups is determined by antenna size, the frequency, and a user-specified maximum allowable error (in dB). STEP_TRACK mode is active until a time is reached that corresponds to a segment of the satellite's motion which has previously been stored in the track table. When this occurs, PROGRAM_TRACK is activated.

In PROGRAM_TRACK mode the controller smoothly moves the antenna to the positions stored (or derived from) entries in the track table. The time between movements is determined by the same factors which govern the time between peakup operations in STEP_TRACK mode. In particular, the user can specify the maximum allowable error between the antenna's actual position and the position specified by the track table. By increasing the maximum allowable error, antenna movements can be performed less frequently, thus avoiding unnecessary wear on the antenna actuators. In

PROGRAM_TRACK mode the accuracy of the track table is monitored by periodically peaking up the receiver AGC signal. If the error exceeds a level set by the user, all entries in the track table are flagged for update. The period between these accuracy checks is specified by the user, and typically varies from once a day to once a week.

SEARCH mode is entered from STEP_TRACK mode when the satellite signal has been lost. In this mode, the controller periodically searches over a parallelogram-shaped region where the controller has calculated that the satellite will be found. When the satellite is located, the controller enters the STEP_TRACK mode.

The ability to implement the tracking algorithms outlined above is dependent on being able to characterize the mount accurately. This enables the controller to convert position counts into pointing angles and vice-versa. A novel approach to the mount characterization problem has been adopted in the RC2000B/C. The mount transfer function is determined by analyzing the position and longitude data from geo-stationary satellites (which have been specified by the user) in the vicinity of an inclined orbit satellite that the user wishes to track.

In conclusion, the RC2000B/C tracking antenna controllers offer the following unique features....

Ease of setup… In other tracking controllers the user must specify a rectangular search window. The satellite must be observed for 24 hours to insure that the search window is large enough to provide the antenna movements necessary to track the satellite, but small enough so that an adjacent satellite is not within the search window. With the RC2000B/C, the installer is relieved of these chores. The geostationary satellites of interest are located first, then the desired inclined orbit satellite is found, identified, and logged into memory. The setup data which must be entered is straightforward: antenna size, satellite longitude, satellite band (C or Ku), etc.

Accuracy… The accuracy of the system is determined by the resolution of the position sensors, backlash in the mount, and a user-defined variable which specifies the maximum allowable error.

Lower Cost… The RC2000 antenna controllers do not require special actuators or sensors.

1.4 Specifications

A. PHYSICAL

Size:	19.0" x 3.5"H x 9.0"D (Rack) 15.0"W x 3.5"H x 9.0"D (Desk)
Weight:	12.5 lbs.
Temperature:	0-50^{O}C
Input Power:	115/230 VAC, 50/60 Hz., 48 W

B. DRIVE

Output:	12-36VDC, 8.0 Amps 280VA
Sensor Input:	Reed, Hall Effect, Optical

Standard Polarization Interface:
Chaparral type polarotor servo

Optional Interfaces for Motorized Feeds for “A” and “C” models with Potentiometer Feedback:

RC2KPOL: 20 volts DC at 500 milliamps (the RC2KPOL option requires software version 1.40)

RC2KHPP: 5-40 volt DC output (output voltage set by potentiometer (P2) on the RC2KHPP board), 3 amps at 40 volts DC, 400 milliamps at 5 volts DC (the RC2KHPP option requires software version 1.41.

C. NON-VOLATILE MEMORY BATTERY

Duracell DL2450

D. AC INPUT AND DRIVE SUPPLY LINES

These are protected by circuit breakers. There are no user replaceable fuses in this unit.

E. AGC INPUT RANGE:

0-10 volts DC

Chapter 2 THEORY OF OPERATION

2.1 System

Figure 2.1 (page 6) shows two views of the RC2000 chassis. Looking down on the controller from above shows the transformer mounted in the left third of the housing, the drive board in the center, and the digital board on the right. AC Power enter the housing through the back panel on the left. The LCD display and keypad are mounted on the front near the drive and digital boards respectively.

Figure 2.2 (page 7) shows the interconnects between the major subassemblies of the RC2000. The primaries of the transformer are connected to the power entry module through the front-panel switch / circuit breaker. A secondary drive breaker is located in the back panel. AC power from the transformer secondaries enters the drive and digital boards through Molex connectors. Ribbon cables provide the interconnect between the digital board and the drive board, the keypad, and the display.

2.2 Digital Board

The digital board, shown in Figure 3 is 7 3/4 inches long, 5 3/4 inches wide, and 2 inches tall with the installed components. The board contains two 16-pin header connectors J2 for the LCD display and J7 for the drive board. A single 14-pin header provides connection to the rotating feed drive option. The back side of the board holds the 11-terminal interface connector, J1 and DB-9 female connector J5 that in the communications interface.

The digital board for the RC2000 antenna controller, shown schematically in Figure 4, contains the 8097BH micro-controller and its support peripherals, the interface to the 4 by 4 matrix keypad, the interface to the 2 row by 40 column LCD (liquid crystal display) module, the Programmable Logic Devices (PLD) which control the solid state azimuth and elevation motor drives, the azimuth and elevation position sense pulse counters, the analog voltage signal strength inputs (also referred to as the AGC inputs - Automatic Gain Control inputs), the transceivers for the serial RS-422 serial port, the polarotor drive circuits, and the 5 volt power supply.

2.2.1 8097BH Micro-Controller and Support Peripherals

The RC2000 is based on the Intel 8097BH micro-controller running at 10 MHz in the 8-bit bus mode. The 8097BH is a 16 bit micro-controller with 230 onboard 8 bit registers, an asynchronous serial port, an 8 channel 10 bit Analog to Digital converter, built-in timers, and a high speed I/O system.

The micro-controller and its support peripherals consists of the following components:

The 8097BH micro-controller (U1) is running at 10 MHz in the 8-bit interface mode.

An Intel 5C032 Programmable Logic Device (PLD) (U2) decodes the latched address and provides chip select signals to the EPROM, static RAM (random access memory), real time clock (RTC), and parallel port. The static RAM chip select line is active high; all other chip selects are active low.

The 74LS373 latch (U3) latches the lower 8 address bits. The upper address bits are latched by the micro-controller. The controller software is stored in the 27C512 EPROM (electrically programmable read only memory) (U4). The 27C512 is configured as 8 bits by 64 Kilobytes.

Figure 2.1 RC2000 Top and Front Views

Figure 2.2 RC2000 Interconnection Diagram

The 6264LP is an 8K x 8 low power static RAM (U5) with battery backup provided by circuitry on the digital board. The static RAM uses 2 chip selects. CE2 is an active high chip select which is produced by U2. /CE1 is an active low chip select produced by U7. /CE1 insures that if a powerdown occurs during a write cycle the contents of the static RAM will not be corrupted.

The MSM62X42BRS real time clock (RTC) (U6) integrated circuit (IC) maintains the system time and date. The RTC includes a built-in crystal. The RTC has 2 chip selects. The /CS0 chip select is generated by the address decode PLD. The CS1 chip select is tied to the micro-controller reset line (/RST). If the system powers down during a write to the RTC the CS1 chip select prevents corrupt data from being written to the RTC.

IC U7 is the Maxim MAX691 microprocessor supervisory circuit. This circuit provides a number of important functions...

When the system is powered down this circuit provides battery power to the static RAM and the RTC.

On powerup, this IC holds the active low microprocessor reset line (/RST) low until the system power has stabilized. The active high reset RST is used to initialize the 82C55. The /CE OUT output is used to control one of the chip selects for the static RAM. This prevents corrupt data from being written to the RAM during a powerdown. The /RST line performs a similar function with the RTC

The PFI input and the voltage divider formed by R5 and R6 is used to monitor the battery voltage. If the battery voltage falls below 2.275 volts the /PFO output signals the micro-controller that the battery voltage is low.

The 82C55 (U8) provides three 8 bit parallel I/O ports. Port A is configured for input, and ports B and C are configured for output.

2.2.2 Keypad

The controller uses a 4 by 4 matrix keypad. The keyswitches are closed when the user depresses a key. The micro-controller detects keystrokes by causing each row of the keypad to sequentially strobe low and then monitoring the keypad column inputs. The keypad column inputs are pulled high with resistor network RN4. The 74LS156 2 to 4 line decoder (U12) is used to strobe the keypad rows low. The decoder has open collector outputs so that if two keys are depressed simultaneously there is no contention between decoder outputs. When a key is depressed, that key's column input to the 82C55 will be low when the key's row is strobed low by the decoder.

2.2.3 LCD Display

The LCD is connected to port 1 of the micro-controller. The LCD is used in 4-bit interface mode. Potentiometer P1 adjusts the contrast of the LCD display.

2.2.4 Motor Control Circuitry

The azimuth and elevation axis motors are powered by a pair of MOSFET based H bridge control circuits. The upper MOSFETs of each bridge are P channel type and the lower MOSFETs are N channel type. The individual MOSFETs of the H bridges are controlled by a pair of state machines implemented via Intel 5C060 PLDs (U9 azimuth, U10 elevation). The state machine clocks are derived from the 3.33 MHz micro-controller CLKOUT (clockout) output.

2.2.5 Description of the signals which control the state machine and which are generated by the state machine

Figure 2.3 Digital Board Layout

Figure 2.4 Digital Board Schematic

MODESEL2, MODESEL1, MODESEL0 ... these signals are generated by the micro-controller. These signals are the commands for the state machine. Here are the various commands which may be present on these lines ...

BRAKE (000) ... the two lower MOSFETs of the bridge are on. This mode is used to stop the motors by means of dynamic braking.

IDLE (001) ... all MOSFETs off. This state is active when an alarm is detected.

SLOW MOVEMENT EAST or DOWN (010) ... In this mode the motors are pulsed on and off to achieve slow speed movement. The source of the pulse is the TACHIN input to the PLD. The TACHIN input is generated by the micro-controller.

SLOW MOVEMENT WEST or UP (011) ... In this mode the motors are pulsed off and on to obtain slow speed movement in either the west or up direction.

FAST MOVEMENT EAST or DOWN (100) ... In this mode the motors are turned on to achieve fast movement in either the east or down direction.

FAST MOVEMENT WEST or UP (101) ... In this mode the motors are turned on to achieve fast movement in either the west or up direction.

RESET ... This mode commands the state machines to reset the alarm state.

ALARM ... This mode commands the state machine to enter the alarm state.

TACHIN ... This input is generated by the micro-controller. It is used to pulse the motors off and on during slow speed movement. The RC2000 implements a digital servo system. When the user specifies a slow speed code, he or she is indirectly specifying the desired rate at which position pulses will occur when the antenna is moving slow. The micro-controller varies the pulse width modulated waveform on the TACHIN pin to vary the speed of the motor so that position pulses arrive at the rate specified by the slow speed code.

ALMLATCH (alarm latch - pin 21) ... This output from the state machine drives the alarm relay on the analog board. The alarm relay is opened whenever an over-current condition is detected by the state machine or the state machine is commanded to enter the alarm state by the micro-controller.

ASTAT1, ASTAT0 ... These outputs (from the state machine) are used to inform the micro-controller of the alarm status of the state machine. 00 means no alarm, any other combination means that the state machine is in the alarm state.

The state machine clock is derived from the micro-controller CLKOUT output. Whenever the micro-controller changes the mode bits the clock to the state machine is disabled. The clock to the state machine is present on pins 1 and 13 of the PLD. The CLKOUT pin of the micro-controller is connected to the CLKIN pin of the PLD. The microcontroller controls the clock via the CLKEN (clock enable) input to the PLD. The PLD logically ANDs the CLKEN and CLKIN signals to produce the CLKOUT (clockout - pin 22) signal. The clockout signal goes to the 74HC4060 pre-scaler. The input clock frequency is divided down and presented to the CLK1 and CLK2 inputs of the PLD.

2.2.6 Pulse Position Sensors

The pulses from the azimuth and elevation position sensors are processed by a comparator circuit (U15 - azimuth, U16 - elevation). Resistors R13 and R15 form a voltage divider which presents 2.5 volts to the non-inverting input of the LM311 comparator. R17 and R14 are used to create hysteresis in the comparator circuit and eliminate jitter in the output of the comparators.

2.2.7 Signal Strength Input Circuits

The RC2000 accepts 2 analog voltages proportional to received signal strength. The controller will use the strongest signal. The signal strength inputs are normally connected to the AGC (automatic gain control) output of a satellite receiver. Each channel has an offset and gain adjustment. The purpose of these adjustments is to expand the range of the AGC signal output by the receiver for measurement by the micro-controller.

The micro-controller has an 8 channel 10 bit A/D converter which converts voltages in the range of 0 to 5 volts. The range of inputs accepted by the signal strength input circuits is 0 to 10 volts. The first op amp in each circuit is operated in a voltage follower mode. R40 and R45 form a voltage divider. If a greater input voltage range is required a series resistor can be placed on the input. Potentiometer P4 adjusts the gain and potentiometer P3 sets the offset. Components R45, R35, C40, and C41 provide a single stage input filter with a time constant of 39 msec.

2.2.8 RS-422 Serial Port

U13 and U14 are RS-422 transceivers. RS-422 uses a differential signals of 0 or 5 volts. The transmit pins of the RS-422 port are tri-stated when the RC2000 is not transmitting. These features allow many RS-422 devices to be daisy chained together. The transmit enable function is implemented using PC.2 of the 82C55. The data format is 7 data bits with even parity and 1 stop bit at user selectable data rates up to 9600 baud.

2.2.9 Polarotor Drive Circuit

The polarotor drive is implemented using FET Q1. The polarotor has its own separate 5.7-volt supply implemented using VR2. VR2 is a 5-volt regulator. R30 and R31 form a voltage divider which maintains the GND terminal of the voltage regulator at 0.7 volts.

2.2.10 5 Volt Power Supply

VR1 is a 5-volt switching power supply which provides power to the digital board. The input to the voltage regulator is a center tapped 18-volt transformer secondary.

2.2.11 Parts List

The following pages contain the parts list for the RC2000 digital board.

Bill of Materials…RC2KDIG2.S01

Quantity	Type	Value	Ref. Designators
1	27C512		U4
1	5C032		U2
2	5c060		U10,U9
2	75ALS176	75ALS176	U13,U14
1	8097BHN		U1
1	82C55		U8
1	BAT	DL2450	B1

Quantity	Type	Value	Ref. Designators
7	CAP	4.7T	C1,C14,C26,C28,C3,C4,C5
21	CAP	.1	C10,C11,C12,C13,C15,C16,C17,C18,C19,C2,C20, C25,C27,C31,C32,C34,C35,C43,C6,C7,C8
4	CAP	100p	C21,C22,C23,C24
1	CAP	470uF	C30
1	CAP	10	C33
2	CAP	30p	C38,C39
2	CAP	.039	C40,C41
2	CAP	4.7	C42,C9
1	CDM6264	6264LP	U5
1	CRYSTAL	10M	X1
1	DB9F		J5
1	DIODE	1N4685	D1
3	DIODE	1N5396	D11,D7,D8
2	DIODE	1N4737	D13,D14
4	DIODE	MPTE5	D2,D3,D4,D5
2	IDC2X8		J2,J7
1	IND	470uH	L1
4	INTAB2		U20,U21,U22,U23
1	LM2575-5	LM2575-5	VR1
2	LM311NE		U15,U16
2	LMC662C		U18,U19
1	MAX691		U7
1	MSM62X42BRS		U6
8	OUTTAG		U24,U25,U26,U27,U28,U29,U30,U29
1	POLCAP	2200uF	C29
3	POT	5K	P1,P4,P6
1	POT	10K	P2

Quantity	Type	Value	Ref. Designators
2	POT	2K	P3,P5
1	REF02H	REF02H	U17
3	RES	100	R10,R18,R29
2	RES	220	R11,R19
6	RES	470	R12,R20,R26,R28,R39,R44
7	RES	1K	R13,R15,R16,R21,R23,R24,R9
2	RES	5.1K	R14,R22
3	RES	1OOK	R17,R25,R38
5	RES	1M	R27,R35,R40,R45,R46
1	RES	240	R30
1	RES	33	R31
1	RES	6.8	R34
2	RES	20K	R36,R37
1	RES	10M	R4
2	RES	10K	R41,R42
1	RES	430K	R43
1	RES	8.2M	R5
1	RES	7.5K	R6
2	RES	300	R7,R8
1	RES4SIPA	2K	RN1
2	RES4SIPA	4.7K	RN4,RN5
2	RES8SIPI	91	RN2,RN3
1	SCHOTTKEY	1N5821	D10
1	SCHOTTKEY	P6KE27A	D9
1	SN74ALS373N		U3
1	SN74HC4060N		U11
1	SN74LS156N		U12

Quantity	Type	Value	Ref. Designators
1	TMOSN	BS170	Q1
1	TRANZORB	P6KE6.8	D12
1	VOLTREG	LM140-5	VR2
1	ZORB	P6KE6.8	D6

Total Parts: 147

2.3 Drive Board

The motor drive board, located in the center of the RC2000 chassis, contains the circuitry which converts the AC power from the drive winding of the transformer to DC and, using solid-state devices, switches this DC power across the motor drive lines. Other circuitry on the board monitors the current flow to the motors and provides fail-safe drive power interruption.

2.3.1 Assembly Diagram

The drive board, shown in Figure 5 is 7 3/4 inches long, 4 inches wide, and 3 inches tall with the installed components. On the left side of the board is a large aluminum heatsink on which is mounted eight MOSFET devices. On the front of the board near the 3-terminal power inlet Molex connector, J1, are two normally open drive relays. The back side of the board holds the 6-terminal drive output connector, J2. Control of the various board functions is performed by the digital board through the 16-pin header, J3.

2.3.2 Circuit Description

Figure 6 contains the schematic diagram for the drive board. AC power enters the drive board from the secondary of the transformer through connector J1 after having been routed through the rear-panel-mounted, 12 amp, circuit breaker. The power is converted to an unloaded 40 VDC through bridge rectifier, BR-1 and capacitor, C2. Two relays, K1 and K2, provide a normally open connection to the azimuth and elevation drive MOSFETs respectively. These 24 VDC relays are actuated through open collector Darlington drivers U2A and U1A and voltage dropping resistors R12 and R13. A series-pass voltage regulator, VR1, provides a 12-volt supply for the current sensing circuitry. The combination of resistor R38 and diode D11 performs a "pre-regulation" function to limit power dissipation in VR1.

2.3.3 Current Sensing Circuitry

The azimuth drive current flows through a precision power resistor, R17. The voltage drop across the resistor is scaled by the resistor network, R14-R16 and R18-R20. This voltage is presented to the low-pass difference amplifier circuit consisting of OP-AMP U3B and surrounding circuitry. This provides a single ended voltage which is proportional to average current flow with the characteristic of about 0.166 volts/amp. This sense voltage is then presented to a comparator circuit consisting of U3A and surrounding circuit elements. Potentiometer P1 provides the comparison voltage which triggers the drive fault signal, an active high TTL level on pin 8 of header J3 labeled AZ_FAULT. A precision voltage reference, U3E, provides a stable 5.5-volt reference signal for P1. The standard factory adjustment for P1 is for an azimuth test point voltage (at AZ_TP) of 3.25 volts. An exact duplicate of this circuit performs the current sensing function for the elevation axis.

Figure 2.5 Drive Board Layout

Figure 2.6 Drive Board Schematic

2.3.4 FET H-bridge

The DC drive signal is connected across the motor lines through the use of a solid-state switch configuration known as an “H-bridge.” This name arises due to the switch elements being located on the four vertical sections of an “H” and the motor located in the center section of the “H.”

Referring to the azimuth H-bridge portion of Figure 6, drive voltage is applied to the two output lines, AZ Drive 1 and AZ Drive 2, of connector J2 buy turning on alternate pairs of FET devices. To apply forward bias across the output lines, FETs Q2 and Q3 are biased on and FETs Q1 and Q4 are biased off. To apply reverse bias, Q2 and Q3 are biased off while Q1 and Q4 are biased on. By allowing Q1 to remain on, Q2 and Q3 to remain off, and rapidly switching Q4 off and on with a prescribed duty cycle, motor speed can be controlled. By turning off Q1 and Q2, and turning on Q3 and Q4, a low resistance current path is established between the two motor drive lines. This H-bridge mode acts as a dynamic motor break. Metal oxide varistors across the two drive lines and in shunt from each of them to ground provide a degree of protection from lighting strike induced voltage transients. A duplicate of the H-bridge, consisting of Q5 - Q8, performs the switching functions for the elevation axis.

2.3.5 Biasing of the MOSFETs

The MOSFETs used for power switching on the drive board are of two types: P-channel and N-channel. The P-channel devices, Q1, Q2 and Q5, Q6, make the connection between the positive supply and the motor drive lines. N-channel devices, Q3, Q4 and Q7, Q8 are used for making connections between the controllers power supply common node and the motor drive lines. Both the P-channel and N-channel FET are turned on (biased to a low resistance condition) by application of the correct gate-to-source bias voltage.

The bias circuitry for the P-channel FET, Q1, will be explained in detail. The other P-channel FETs, Q2, Q5, and Q6, operate in a similar manner. In the off condition, a logic “0” is applied to the input of the open-collector Darlington driver U2:C. The driver remains in the off condition, allowing the output (pin 14) to float to the drive supply input level. Since no current is flowing through the resistor pair R1 and R2, the voltage presented to the FET gate is very nearly the same as the voltage on the source. This gate-to-source voltage of near zero holds the FET in the “off” condition.

A logic “1” applied to the driver U2:C forces the driver output to the “on” condition with typical levels of 0.9 volts to 1.6 volts. This condition allows current to flow through resistor-pair R1-R2 with their junction being held to 12 volts below the voltage on the FET source (typically 28 volts) by zener diode D1. This voltage is presented to the FET gate which allows the FET to enter the “on” state.

The bias circuitry for the N-channel FET, Q3, will be explained in detail. The other N-channel FETs, Q4, Q7, and Q8, operate in a similar manner. A logic “0” is applied to the input of the open-collector Darlington driver U2:B. The driver remains in the off condition, allowing the output (pin 5) to float to the 12 volts prescribed by the network of R3 and zener diode D2. This voltage is presented to the gate of Q3 through resistor R5 and forces the FET into the low resistance “on” state.

A logic “1” applied to the driver U2:B forces the driver output to the “on” condition with typical levels of 0.9 volts to 1.6 volts. This condition forces the junction of R3 and D2 to this level. This voltage is presented to the FET gate which holds the FET in the “off” state.

The FET bias conditions and drive output polarity for various move commands may be found in the table on the following page.

Command	Azimuth FETs	Elevation FETs	Drive Polarity on J2 output terminals			
			AZ1	AZ2	EL1	EL2
AZ_East	Q1=off,Q2=on,Q3=on,Q4=off	Q5=na,Q6=na,Q7=na,Q8=na	+V	0V	0V	0V
AZ_West	Q1=on,Q2=off,Q3=off,Q4=on	Q5=na,Q6=na,Q7=na,G8=na	0V	V+	0V	0V
EL_Up	Q1=na,Q2=na,Q3=na,Q4=na	Q5=on,Q6=off,Q7=off,Q8=on	0V	0V	0V	V+
EL_Down	Q1=na,Q2=na,Q3=na,Q4=na	Q5=off,Q6=on,Q7=on,Q8=off	0V	0V	V+	0V
“Brake” Mode	Q1=off,Q2=off,Q3=on,Q4=on	Q5=off,Q6=off,Q7=on,Q8=on	0V	0V	0V	0V

2.3.6 Parts List

The parts list for the RC2000 drive board is as follows:.

Bill of Materials…AZELDRV2.S01

Quantity	Type	Value	Ref. Designators
8	IN4742	IN4742A	D1,D10,D2,D3,D4,D7,D8
1	BREAKER	W28-XQ1A-12,P&B	CB1
1	BRIDGE RECT	MB354W	BR1
1	CAP	.039uF	C1
3	CAP	.1	C10,C7,C8
4	CAP	.039	C3,C4,C5,C6
1	CAP	10	C9
4	DIODE	IN4002	D12,D13,D5,D6
1	CONNECTOR	IDC2X8	J3
1	VOLTAGE REGULATOR	LM317TB	VR1
1	OP-AMP/ COMPARATOR	LM613	U3
6	MOV	V68Z10	V1,V2,V3,V4,V5,V6
2	MOV	68-14m	V7,V8

Quantity	Type	Value	Ref. Designators
1	POLCAP	3300uF/63V	C2
2	POT	50K	P1,P2
2	RELAY-SPST	T90S1D12-24	K1,K2
8	RES	3.6K	R1,R10,R2,R28,R29,R36,R37,R9
1	RES	3.6K,.5W	R11
2	RES	390,1W	R12,R13
8	RES	1.1K,1%	R14,R15,R18,R19,R21,R22,R25,R26
4	RES	475,1%	R16,R20,R23,R27
2	RES	.05	R17,R24
5	RES	7.5K	R3,R30,R35,R57,R8
8	RES	27K	R31,R32,R33,R34,R4,R5,R6,R7
1	RES	560/1W	R38
1	RES	240	R39
1	RES	2K	R40
4	RES	8.25K	R41,R42,R45,R46
4	RES	162K	R43,R44,R47,R48
2	RES	200K	R49,R50
2	RES	10M	R51,R54
2	RES	5.1K	R52,R55
2	RES	3.3K	R53,R56
1	RES	2.2K	R58
1	RES	1.0K	R59
4	TMOSN	MTP25N10E	Q3,Q4,Q7,Q8
4	TMOSP	MTH20P10	Q1,Q2,Q5,Q6
2	UNL2003A		U1,U2
1	ZORB	1N454A	D11

Total Parts: 109

Chapter 3 ACCEPTANCE TEST PROCEDURE

This test procedure is followed by test personnel at the factory.

1. Turn on test bench power supplies and voltmeters. Install EPROM, EPLD, and clock devices as specified for the particular model being tested. Verify the orientations of all installed ICs.

2. Place the input voltage switch of the 2000 into the 115V position. Plug in the unit.

3. Turn on the RC2000 using the front panel circuit-breaker/power switch. Adjust the "LCD Contrast" pot, located on the digital board near the ribbon connector J2, to obtain a readable front panel display.

4. Install the coincell battery [Duracell DL2450] in the battery holder on the digital board.

5. Attach the ground leads from the voltmeter and power supply to the RC2000 chassis.

6. Adjust pot P2, labeled "VREF TRIM" located in the front, left corner of the digital board while measuring the voltage at the test point labeled "VREF". Set the voltage at 5.000 VDC.

7. On the drive board, set both the AZ_TP and EL_TP test points for voltage readings of 3.25V using trim pots P1 AZ_CL and P2 EL_CL, respectively.

8. Set SS1 offset voltage at wiper of OFF1 pot P3 (digital board--junction with 10K Resistor R41) to 0.50 VDC using the OFF1 pot P3.

9. Set SS2 offset voltage at wiper of OFF2 pot P5 (digital board--junction with 20K Resistor R37) to 0.75 VDC using the OFF2 pot P5.

10. Adjust the power supply to 0.30V and hookup to the SS1 input (digital board--pin 1 on connector J1). Adjust the gain pot G1 (pot P4) to obtain 3.75V at the SS_1 test point. If testing the "B" or "C" version, go to the limits mode and note the SS1 reading. (should be about 800)

11. Adjust the power supply to 2.5V and hookup to the SS2 input (digital board--pin 2 on connector J1). Adjust the gain pot G2 (pot P4) to obtain 3.75V at the SS_2 test point. If testing the "B" or "C" version, go to the limits mode and note the SS2 reading. (should be about 800)

12. Verify the +12V supply (+12V $\pm$1V) on the digital board by measuring the +12V test point located in the front-left corner of the board

    Verify the +5.7V supply (+5.8V $\pm$0.5V) on the digital board by measuring the +5.7V test point located in the back-left corner of the board.

    Verify the CL circuit supply (+11.8V $\pm$0.5V) on the drive board by measuring the metal case of VR1 located in the front-right quadrant of the board near the large electrolytic capacitor.

    Verify the +5V supply (+5V $\pm$0.1V) on the digital board by measuring the +5V test point located in the front-left corner of the board.

13. Turn off the RC2000 and attach the cables to the test mount at connectors J1 and J2.

14. Turn the unit on. It should come up in limits mode. Toggle the mode key to bring up CONFIG mode. Scroll up to RESET SYSTEM DATA" and then enter the 41758 code. IF RESET SYSTEM DATA does not appear during the scrolling, then expert access mode must be turned on with the 41758 code. After a successful system data rest the unit should return to limits mode.

15. In limits mode press any key to continue. Set the east limit by pressing the "E" key and verifying that the AZ count value is decreasing. Then press 7 to set the east limit. The AZ count should now

read thirty. Set the west limit by pressing the "W" key and verifying that the AZ count value is increasing. Then press 7 to set the west limit. Hit the BKSPC key to confirm the limits setting.

16. Set the down limit by pressing the "S" key and verifying that the EL count value is decreasing. Then press 9 to set the down limit. The EL count should now read 30. Set the up limit by pressing the "N" key and verifying that the EL count value is increasing. Then press 9 to set the UP limit. Hit the BKSPC key to confirm the limits setting.

17. If the controller is the "B" or "C" version go to CONFIG mode and scroll to "ENTER DATE" to set the date and time.

18. Return to config mode and scroll to REMOTE MODE ENABLE. Set it to 1. (this is not available on the RC2000B) Scroll to AUTOPOL ENABLE and set it to 1.

19. Toggle the mode key to reach SETUP mode. Test the speed control algorithm by pressing the "Speed" key for a "SLOW" speed display and pressing the "E" key for mount movement. The speed servo should display status beginning with around 12 on the display ramping up to about 24. This should accompany a motor speed increase. Repeat this for "S" motion.

20. Select any Satellite from the scrolling list other than the "USER" entry. For "B" and "C" versions select "NO" for inclined orbit operation. Enter 0.0 for the satellite longitude. Hit enter for east longitude and select 2, "USER ENTRY" for the polarization data.

21. Press CW and note the movement of the test polarotor. Press H to set. Press CCW and note the opposite movement of the test polarotor. Press V to set. The RC2000 should now display "DATA ACCEPTED".

22. Cycle the power on the RC2000 off, then on. The software should come up in manual mode.

23. Test the autopol function by shorting the probe attached to the H/V input (pin 8 connector J1) to ground. This action should skew the test polarotor between the two previously stored polarization positions.

24. The following remote mode test is only valid for "A" and "C" versions. Attach the test communications cable to the comm. port, J3. Run the program RC2K.EXE on the test computer. Select the baud rate D, 9600. Select the comm. port in use. Enter "C" and type in the device address of "50". Type the letter "E" on the computer keyboard. The PC screen should contain data in both the top (transmit half) and bottom (receive half) of the screen. "REMOTE" should appear in the upper right hand corner of the RC2000 display.

25. The following feed drive test is valid only for "A" and "C" versions that contain the optional rotating feed drive, option RC2KPOL. Install and connect the optional feeddrive. Adjust pot P1 so that the voltage on the reference pin (pin 3) of the feeddrive is 5.0V. Turn on the RC2000 and attach the rotating feed test plug to the feeddrive under test. Turn on the unit; go to CONFIG mode and scroll to the item, POLAROTOR PRESENT. Set this item to 0. Scroll to Autopol enable and set this item to 0. Go to manual mode, press "CW" and "CCW" to verify rotation of the test feed.

26. Go to CONFIG mode, scroll to RESET SYSTEM DATA, and type in the code 41758. Test Completed.

Chapter 4 COMMON RC2000 QUESTIONS

4.1 Invalid Data Entry

This error can occur in AUTO mode when the user attempts to position the antenna on a satellite which has been previously stored in non-volatile memory (satellites are stored in non-volatile memory via SETUP mode) and either the azimuth, elevation, horizontal polarization or vertical polarization data fields contain invalid data. In this context, invalid data means that the data lies outside the limits associated with that axis.

4.1.1 Background

When a user stores a satellite in non-volatile memory of an RC2000A the following data elements are actually loaded into memory...

The satellite name (10 alphanumeric characters), the satellite azimuth and elevation position (in position counts - 30 to 65535), the satellite horizontal and vertical polarization positions, and the satellite longitude.

For an RC2000C the following additional information is also stored in non-volatile memory: a flag that indicates whether or not the satellite is in an inclined orbit, the inclination of the satellite's orbital plane with respect to the earth's equatorial plane (at the time the satellite was stored in memory), and a code that indicates the satellite band (C or Ku).

4.1.2 Events Typically Associated with the INVALID DATA ENTRY Error Message

This error is generally caused by one of two events...

1. The user has redefined the azimuth or elevation limits, or

2. The user has changed the type of polarization control device via the Rotating Feed Present CONFIG mode item.

4.1.3 Azimuth and Elevation Limits

The azimuth and elevation limits are set by the user in LIMITS mode. The INVALID DATA ENTRY alarm can occur if the user...

1. Initially sets the azimuth and elevation limits, then

2. programs some satellites into non-volatile memory, then

3. changes the azimuth and elevation limits (via LIMITS mode) so that the antenna's range of azimuth or elevation movement is reduced relative to initial azimuth and elevation limits defined in step 1,

4. If the user attempts to recall (via AUTO mode) a satellite programmed into memory in step 2 and the azimuth or elevation position associated with that satellite entry is outside the CURRENT azimuth or elevation limits the controller will not perform the automatic move and the INVALID DATA ENTRY message will be displayed.

4.1.4 Changing the Polarization Control Device Associated with the Controller

The RC2000 supports two types of polarization control devices...

1. A servo type polarization control device based on the Chaparral polarotor. The polarotor has a three wire interface (5 volts DC, Pulse, and Return). The controller positions the polarotor by sending a pulse width modulated (pwm) waveform to the polarotor. The off time of the waveform is fixed at 15 to 20 milliseconds (msec) and the on time varies between 0.8 msec and 2.2 msec. As the on time of the waveform changes the feed's polarization angle varies over a range of approximately 200 degrees. The servo type interface is completely open loop meaning that the controller has no indication of what the polarotor's actual polarization position is or if a polarotor is even connected to the device.

2. The RC2000 can optionally control a rotating feed powered by a 24 volt DC motor (500 ma max) that uses a potentiometer for position feed back such as the Seavey Engineering model ESA 124D four port rotating feed. To support this option the RC2KPOL daughterboard must be installed in the RC2000.

The user selects the polarization control device via the Rotating Feed Present CONFIG mode item. If the item is set to 0 (NO) the controller assumes that it is interfaced to a polarotor type device. If the item is set to 1 (YES) the controller assumes that it is attached to a rotating feed type polarization control device.

If the controller is configured for use with a polarotor type device the controller's internal representation of any valid polarization position is a number between 293 (for a clockwise - CW - limit) and 956 (counter clockwise - CCW - limit). The user does not specify the limits for a polarotor type device.

If the controller is configured for use with a rotating feed type polarization control device the user must specify the limits. The maximum possible range of polarization movement is 0 to 1023. For the RC2000A the user sets the polarization limits via the POL LIMITS mode. With the RC2000C the user sets the polarization limits via the CONFIG mode Rotating Feed CW Limit and Rotating Feed CCW Limit items.

4.1.5 INVALID DATA ENTRY Error Message Due to Polarization Position Data

The INVALID DATA ENTRY message will be displayed anytime the user attempts to position the antenna on a satellite and the polarization positions stored in the satellite's non-volatile memory data entry are outside the current polarization CW and CCW limits for whatever type of polarization control the RC2000 is currently configured to support. As shipped from the factory, the default rotating feed CW and CCW limits are 500 and the Rotating Feed Present CONFIG mode item is set to 0 (NO).

One case where this error can occur is if the user has specified a Seavey type rotating feed (via the CONFIG mode Rotating Feed Present item) and does not have a feed or RC2KPOL daughterboard connected to the controller. As shipped from the factory, the default rotating feed CW and CCW limits are 500. If there is no rotating feed connected the controller's sensed polarization position will be either 0 or 1023 and the controller will store either 0 or 1023 for the horizontal and vertical polarizations. When the user programs a satellite into the controller's memory via SETUP mode the controller DOES NOT check to see that the polarization data is within the current polarization limits - the user will see the SETUP mode DATA ACCEPTED message. However, when the user attempts to move (via AUTO mode) to the satellite that has just been entered (via SETUP mode) the controller will display the INVALID DATA ENTRY message because the current polarization CW and CCW limits are set to 500 (or some other values) but the satellite's entry in non-volatile memory specifies that the horizontal and vertical polarization positions are 0 or 1023.

Another case where this can occur is if the controller is configured for one type of polarization control device, say a polarotor, when a satellite is programmed into non-volatile memory but the user later changes the polarization control device (in this example to a rotating feed). If a polarotor is originally specified when the data is stored in non-volatile memory the horizontal and vertical polarization values stored for the satellite will be between 293 and 956. If the polarization control device is later changed to a rotating feed device and the user attempts to recall the satellite, the polarization positions stored in non-volatile memory may be outside the current polarization CW and CCW limits. This will again result in the INVALID DATA ENTRY message being displayed.

It is not possible to edit an entry in non-volatile memory. The user can only delete (using DELETE mode) or overwrite (via SETUP mode by specifying the name of a satellite which is already stored in non-volatile memory) a satellite's non-volatile memory entry.

4.1.6 No Polarization Control Device Attached to the RC2000

If there is no polarization control device used with the RC2000 the controller should be configured for polarotor operation. This is done by setting the Rotating Feed Present CONFIG mode item to 0 (No). When storing a satellite in memory (via SETUP mode) make sure that the current polarization position (displayed to the right of the POL: or PL: banners) is not at the CW or CCW limit. Use the polarization jog keys (labeled POL CW or POL CCW) to 'jog' the polarization out of the limit condition.

4.2 Antenna Azimuth and Elevation Errors

An antenna azimuth or elevation error is indicated on the controller by a flashing ANT AZIM or ANT ELEV message on the bottom row of the display. The cause of the error is displayed via RESET mode. These errors are triggered by one of three possible events:

1. The antenna was commanded to move and an overcurrent conditions occurred. In this case the RESET mode azimuth or elevation error status will display as DRIVE. The RC2000 uses a solid state drive. The current threshold is 8 amps. There are current limit threshold adjustments on the controller's drive board (the one with the heat sink).

2. The antenna was commanded to move and no movement was sensed. In this case the RESET mode elevation error status will display as JAMMED. This could be caused by the antenna actually being jammed or the sensor could have failed (the antenna was really moving but the movement was not sensed). If the position sensor failed the controller's position count would be in error.

   Note that there is also a thermal circuit breaker present on the controller which protects the drive circuits. A tripped circuit breaker can trigger the JAMMED alarm. The circuit breaker is accessible via the back panel. The circuit breaker has tripped and needs to reset if the button on the circuit breaker is protruding from the mounting bezel. Reset the breaker by depressing the button. It may be necessary to wait several minutes before the button will stay in.

3. The antenna was not commanded to move and movement was sensed (i.e. a position pulse was received). When this error occurs the RESET mode elevation error status will display as RUNAWAY. This error can be caused by:

   i) Noise Pickup on the Sensor Lines. Please see the section on Position Count Errors.

   ii) The Az/El Fast Deadband or Az/El Slow Deadband CONFIG mode items need to be increased. When the antenna has been moving and is suddenly commanded to stop, the antenna must coast to a stop within 'Fast Deadband milliseconds if the antenna was moving fast or within 'Slow Deadband milliseconds if the antenna was moving slow. If the antenna moves at a single speed the 'Fast and 'Slow Deadband values MUST be set to the same value.

   If a position pulse is received by the controller and the controller is not either moving or in a coast period defined by the Az/El Fast/Slow Deadbands described above a RUNAWAY error will occur.

   If the RUNAWAY error occurs immediately after an antenna move it is probably due to insufficient 'Fast or 'Slow Deadband intervals.

   For RC2000C model antenna controllers the RUNAWAY error can be disabled. See section 7.3 of the controller manual. Note that it is generally not advisable to disable RUNAWAY error sensing.

   iii) The position sensors are placed on the fundamental axis of the controller. The controller is designed to be used with antenna's powered by linear actuators which have the position sensors located on the 'motor' side of the gear reducer. With the position sensors placed on the 'motor' side of the gear reducer, wind loading will not generate stray position sense pulses.

   If the position sensors are located on the fundamental axis of the antenna, movement due to wind will cause position counts to be produced. The pulse sense circuits of the RC2000 are normally always

active - anytime a pulse is received it increments or decrements the position count based on the direction the antenna was last commanded to move. If a position pulse is received by the controller and the controller is not either moving or in a coast period defined by the Az/El Fast/Slow Deadbands described above a RUNAWAY error will occur.

Any time the controller is tracking an inclined orbit satellite and a system error occurs, tracking will halt and the '**ERROR** SYSTEM" message will be displayed. A system error is any error which generates a flashing alarm message on the bottom row of the display.

4.3 Antenna Position Sense Errors

The RC2000 antenna controllers are designed to work with pulse type sensors - either reed or Hall Effect. The controllers can also be used with most electro-optical based pulse sensors. 5.7 volts DC is available at the back of the controller to power Hall Effect or electro-optical based sensors. Position sense errors affect the positioning repeatability of the controller. Repeatable antenna positioning is the main requirement of the antenna controller.

One way to test the positioning accuracy of the controller is to repeatedly move the antenna between 2 satellites stored in the controller's memory. If the controller is experiencing position pulse count errors the antenna will not return to the peak power position for the satellites. As the antenna is repeatedly moved between the pair of satellites, the pointing error will increase.

If the antenna controller is used to track inclined orbit satellites, count errors can be easily seen by plotting the figure eight pattern of the satellite's apparent motion described by the azimuth and elevation values contained in the controller's program track table. These track table coordinates can be obtained from the TRAK mode Menu system via the View function. If count errors have occurred the figure 8 pattern will not close on itself.

4.3.1 Causes of Antenna Position Count Errors

1. Noise - The cables used to connect the position sensors to the controller must be shielded. Conductors used to carry motor drive current must not be enclosed within the same shield that is used for the sense lines. The position sense cable drains should only be connected at the controller. If the cable is spliced the drain wires must also be connected at the splice. The drains should not be allowed to come in contact with earth ground at the antenna or at any breaks or splices in the cable. More information on position sensor cabling is available in Chapter 3 of the RC2000 manual.

   If the source of the noise is something other than the drive current of the motor of the axis which is experiencing the errant count a RUNAWAY error will probably occur. RUNAWAY errors are described in the section on Antenna Azimuth and Elevation Errors.

2. The position sensors are placed on the fundamental axis of the controller. For a description of the errors caused by placement of the position sensors on the fundamental axis of the antenna controller please see the Antenna RUNAWAY error, item iii, above.

3. Occasionally, position sensor modules fail. This will generally occur on new actuators. If antenna count errors persist on a given axis after the cable shield connections have been verified and RUNAWAY errors are not occurring, the sensor may be dropping pulses. With reed type sensors this can occur when the reed switch element is not oriented properly in the module. For any type of sensor loose connections can also cause count errors.

4.4 Track Mode Limit Error

When a track mode limit error occurs tracking will cease and the controller will display the following error message (as long as TRAK mode is active) '** ERROR ** LIMIT '. This error message should not to be confused with the track mode peak limit error message which is '** ERROR ** PEAK LIMIT'.

The limit error occurs when the antenna controller is tracking an inclined orbit satellite and one of the antenna azimuth or elevation limits is reached. For the RC2000B models this can occur either when then controller is in the Search sub-mode performing a search or when the antenna is being peaked in either the Step Track or Program Track sub-modes. For the RC2000C the search is truncated at the antenna limits so this error can only occur when an antenna peakup is in progress.

If this error occurs while peaking the antenna there is really nothing else to do but reset the antenna limits or reconfigure the actuators to allow greater movement of the antenna. For the RC2000B and RC2000C POLAR models the procedure for setting up the mount is described in the addendum to the manual entitled 'Addendum - RC2000C POLAR and RC2000B POLAR Antenna Controller'.

If the error occurs while the Search is in progress the search window may be either too large or not centered properly. The apparent motion of an inclined orbit satellite is a narrow figure eight shaped pattern. The height of the figure eight (in degrees - as seen from the surface of the earth) is approximately 2.4 times the inclination of the satellite's orbital plane to the earth's equatorial plane (i.e. for a satellite with a four degree inclination the height of the figure eight is approximately 10 degrees). The center of the figure eight will be located on the Clarke belt (where the geostationary satellites are located). The controller calculates the height of the figure eight based on the satellite inclination specified by the user in SETUP mode.

If the controller is experiencing Limit errors while searching make sure that the inclination specified via SETUP mode is not too large. Note that the inclination of an inclined orbit satellite's orbit increases by approximately 0.9 degree per year.

The width of the controller's search region is controlled by the Azim Search Scale Factor CONFIG mode item (in the RC2000B) or the Search Width CONFIG mode item (in the RC2000C). The nominal value of this item is either 3 or 5. If the search window is too wide an adjacent satellite may be 'found' during a search. Generally the value of this item can be reduced to 1 or 2 without any negative effects.

The center of the figure eight for POLAR trackers is the Geo Position Count specified by the user in CONFIG mode. For the RC2000B AZ/EL the center of the figure eight is calculated based on the positions of geostationary satellites in the vicinity of the inclined orbit satellite. ALWAYS VERIFY THE LONGITUDE VALUES ASSIGNED TO GEOSTATIONARY SATELLITES.

4.5 Gaps in the Program Track Table

A peakup will not occur if there is no signal strength (as defined by the K/L or C Band Threshold CONFIG mode items). If the transponder on the satellite is down at the sidereal times which correspond to a given track table entry a peakup will not occur and no data will be entered into the track table.

Another event can cause gaps in the track table. To see this it is necessary to know what triggers peakups when the STEP track sub-mode is active. When the STEP track sub-mode is active, two events can cause the controller to initiate a peaking operation.

The first event is if the sidereal time equals a time which corresponds to one of the 48 points in the track table. These sidereal times are: N * 86164 / 48 where N = 0.47. The current sidereal time can be viewed via the TRAK Menu described in the manual.

The second event which can trigger a peaking operation is a bit difficult to understand. The controller remembers the time when the last peaking operation has occurred. The controller also knows the size of the antenna and the frequency of operation. This allows the controller to calculate the antenna's radiation (or gain) pattern which is a relationship between signal loss and the angle from antenna boresight. The controller also knows the inclination of the satellite (this is obtained when the track is initiated via SETUP mode). By knowing the inclination of the satellite the controller can calculate the angular velocity of the satellite as seen by the controller when that angular velocity of the satellite is at its greatest (i.e. when the

satellite is passing through the earth's equatorial plane). A peakup will be triggered when the time since the last peakup equals a value that corresponds to a pointing error of Max Track Error dB at the maximum angular velocity of the satellite as seen by the antenna. The Max Track Error is specified via CONFIG mode.

If a peakup triggered by the second event is IN PROGRESS when the first event occurs the peakup position will not be entered into the table. This can occur on the RC2000B AZ/EL and RC2000B POLAR. This problem can be avoided with the RC2000C model antenna controllers. The RC2000C allows the user to specify the amount of time that it takes to perform a STEP track peaking operation. The controller will not allow peakups just before a sidereal time which corresponds to an entry in the track table. See Section 7.3 of the RC2000C manual.

4.6 TRACK Mode PEAK LIMIT Error

The PEAK LIMIT error indicates that the controller had to move the antenna too far during a STEP TRACK peaking operation. The maximum movement of the antenna from the starting position for a STEP TRACK operation is limited to prevent the antenna from peaking up on an adjacent satellite. PEAK LIMIT errors may be caused by the following:

1. Specifying too large of an antenna diameter or specifying Ku band when tracking a C band satellite. These cause the controller to calculate too narrow of an antenna beamwidth. The calculated antenna beamwidth is used to determine the maximum allowable movement from the starting position for a STEP TRACK operation.

2. Specifying too small of a satellite inclination. In STEP TRACK mode, the controller performs peakups often enough so that the maximum antenna pointing error specified by the Max Track Error CONFIG mode item is not exceeded. If the specified satellite inclination is too small, the peakups will not occur often enough and the antenna may move far enough during a peakup to trigger the PEAK LIMIT error.

3. The C Band AGC Threshold or the K/L Band AGC Threshold is set too low. If the threshold values are set too low, when the transponder powers down, the AGC signal of the receiver (antenna iooking at noise) may be above the threshold. In this case the controller would mistakenly assume that the satellite signal is present and attempt to peak up on the noise.

4. If the error occurs during a peakup operation while the PROGRAM TRACK submode is active it may be that the Update Check Interval TRACK mode MENU item is set too large.

5. Play or looseness in the mount. This is discussed in the section on mechanical hysteresis. If the step size used for peaking the antenna is approximately the same as the mechanical hysteresis, when the antenna is commanded to move the actuator will be energized but the pointing angle of the antenna may not change. This can lead to PEAK LIMIT errors.

4.6.1 Mechanical Hysteresis in the Mount

If the controller moves the antenna to the correct position (count value) during an automatic move but the antenna must be peaked manually to peak up the signal there may be some play in the mount or the actuator. Note that if the error increases as more movements occur it is probably a sensor problem - see the section on Antenna Position Sense Errors for more information.

When there is play in the mount the antenna will peak up in one position when approaching the satellite from the west and another when approaching the satellite from the east. To test for this move the antenna quite a distance west of the satellite and manually move the antenna east at slow speed until the peak is reached. Repeat the procedure when approaching the satellite from the east. The difference in azimuth position between the 2 peaks is the mechanical hysteresis.

4.7 DH Gibralter Mounts

The DH antenna uses a chain drive for the azimuth axis. There is not much resolution on that axis (800 counts per radian for azimuth versus 2600 counts per radian for elevation). The DH antenna is equipped with a chain tension adjustment on one end of the chain. This adjustment is a threaded rod which tightens up the chain. To tighten the chain position the antenna so that the azimuth drive sprocket is opposite the chain tension adjustment and then tighten up the nut on the threaded rod.

There will always be some looseness in the chain. If the controller calculates that the step track azimuth step size is 1.49 counts the controller will move the antenna 1 count in azimuth - there are no fractional counts. If the slop in the antenna is 2 counts then moving the antenna 1 count in azimuth "may not change the actual pointing angle of the antenna". This is the most common cause of PEAK LIMIT ERRORS. The solution is to increase the MAX TRACK ERROR which will result in larger step sizes.

4.8 AGC Input Notes

It has been found that the AGC (Automatic Gain Control) output of the Drake ESR 1250 Receiver requires a 50K to 100K pull down resistor to work properly with the RC2000 AGC input circuits. On the back of the receiver, the resistor can be connected between the TM (tuning meter) and GND (ground) terminals. Other Drake models may also require this fix.

4.8.1 AGC Input Voltage Range

The AGC input voltage range of the RC2000 is 0 to 6 volts. An input voltage above this range will result in saturation of the output of the AGC signal processing circuit. It is possible to extend the range of the input voltage by placing a resistor in series with the input.

Here is a schematic of the input of the AGC processing circuit …

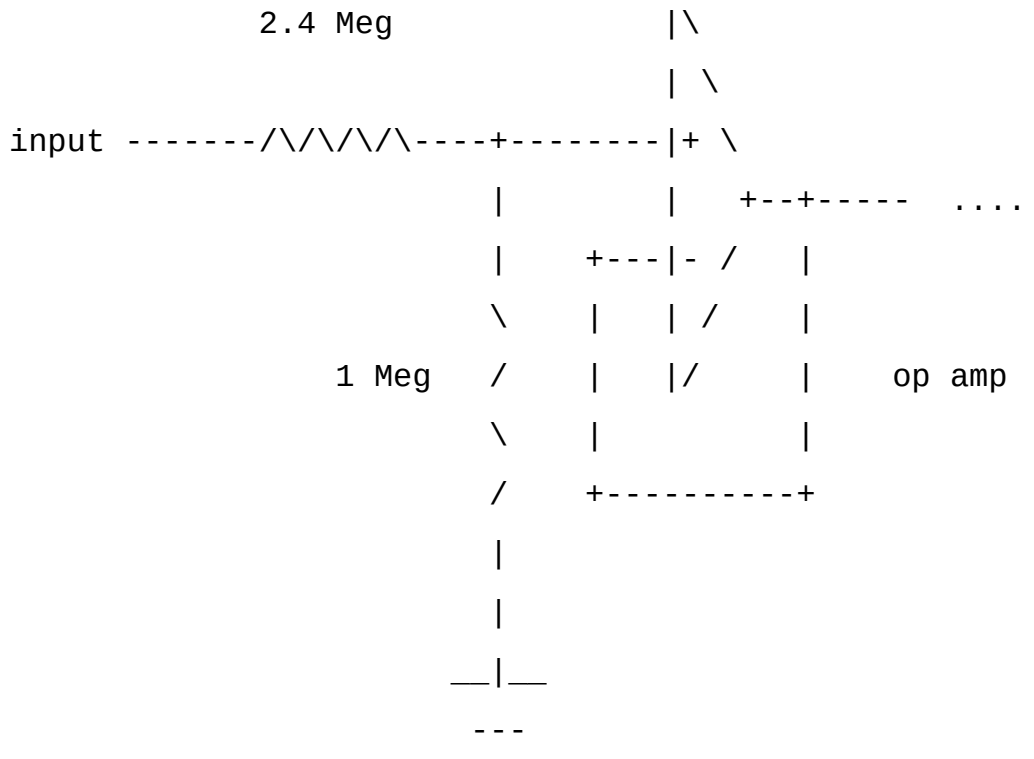

Figure X

The AGC input circuit consists of a voltage divider implemented with a 2.4 and 1 Meg ohm resistors followed by an op amp voltage follower (see Figure X). The maximum common mode input voltage of the op amp is approximately 3 volts (worst case). If the input to the voltage divider exceeds 10.2 volts. the voltage at the input of the op amp will exceed the common mode voltage. To extend the range of AGC input a resistor can be placed in series with the input. For example, if a 1 Meg resistor is placed in series with the input, a 13.4 volt input voltage will result in 3 volts at the input of the op amp.

In the event that the AGCsignal from the receiver is very noisy, it is possible to place an additional filter section in series with the AGC input. The filter section consists of a series resistor and shunt capacitor. A good starting point for component values is 20K ohm for the resistor and 2.2uF for the capacitor. This combination will result in a time constant similar to that in the RC2000 and assumes a low AGC port output impedance. The component values will vary with the output impedance of the receiver AGC port, and some experimentation may be necessary. If the output impedance is very high, it may be possible to do away with the series resistor altogether.

Chapter 5 UPGRADING THE RC2000

5.1 Updating RC2000 and Nomad Model Antenna Controllers

This paper describes the procedure for upgrading the software (contained in an EPROM memory chip) of early model RC2000A (Nomad I), RC2000B (Nomad II), and RC2000C antenna controllers. Early versions of these controllers contain 64k x 8 static RAM (SRAM) chips. Current versions of these controllers contain 8k x 8 SRAM chips. To run the latest software it is necessary to change the memory map of the controller. Any model RC2000 antenna controller can be converted to any of the various versions of the software ('A, 'B or 'C).

To upgrade an early controller to a newer software version, it is necessary to replace the controller's EPROM memory chip and sometimes the memory select PLD (programmable logic device) chip. When upgrading from an RC2000A to either a RC2000B or RC2000C it is necessary to install a real time clock chip. The real time clock chip is an OKI model M62X42B.

Changing the EPROM or PLD has the undesirable side effect of wiping out all data stored in the controller's non-volatile memory. The procedure outlined in this document allows the user to quickly restore the controller's non-volatile memory.

5.2 Installing the Upgrade and Restoring Non-Volatile Memory

Here is the procedure for upgrading the software on early model antenna controllers. The use of this procedure will allow the user to change the controller's memory map and restore the original non-volatile memory contents. If the software is being upgraded on a unit which is not in service, it is not necessary to perform this procedure - simply replace the chips and perform a memory reset (from CONFIG mode) to upgrade the software.

Here is the procedure:

1. In manual mode, jog the antenna to the west and up limit. Record the position count value for each axis just before the limit is reached. (If position display in degrees is enabled, disable that feature before starting this procedure - this feature is available only for certain software versions).

2. Go to CONFIG mode and record the value of each CONFIG mode item.

3. Using AUTO mode, position the antenna on each of the geostationary satellites stored in non-volatile memory. Record the azimuth and elevation positions and the longitude value of each geostationary satellite. Use the H and V keys to position the polarotor. Record the H and V positions for each satellite.

4. Move the antenna to the position just before the east and down limits are reached. This should correspond to a position count value of 30 for both the azimuth and elevation axis.

5. Turn the unit off. Replace the EPROM (U4) and PLD (U2) chips. If the controller is being upgraded to a tracking system from a nontracking system, make sure that a real time clock chip is present in socket U6. Make sure that the chips are oriented properly in the sockets. The notch on the chip should line up with the notch of the outline silk-screened onto the printed circuit board under each IC socket. Make sure that the legs of the chips do not bend up under the IC when they are inserted into the sockets.

6. Verify that the chips are oriented properly in the sockets. Power the unit up. Go to CONFIG mode, bring up the 'RESET SYSTEM DATA' item, and key in 41758 followed by the ENTER KEY to reset the memory.

7. Go to LIMITS mode. WITHOUT MOVING THE ANTENNA set the down and east limits. AFTER THE EAST AND DOWN LIMITS HAVE BEEN SET, jog the antenna to the positions for the west and up limit recorded in step 1. Set the west and up limits. After the west and up limits have been set, exit LIMITS mode by hitting the MODE KEY.

8. Go to CONFIG mode and key in the data recorded in step 2 above. Each entry must be terminated with the ENTER KEY. After the data has been entered scroll through the CONFIG mode items (using the SCROLL UP and SCROLL DOWN keys) and make sure that the data has been entered correctly.

9. In this step, the positions of the geostationary satellites are stored in non-volatile memory. Go to SETUP mode. Position the antenna on each of the satellites which were recorded in step 3 above. Select the satellite name, enter the satellite longitude, and move the polarotor to the recorded H and V positions in response to the appropriate SETUP mode prompts.

Chapter 6 USING THE RS232-RS422 PROTOCOL CONVERTER

6.1 RC1KADP RS232 to RS422 Protocol Converter

The serial port on RC1000A and RC2000 antenna controllers uses RS422 signal levels. This allows the antenna controllers to be connected in a daisy chain fashion (i.e. a single PC equipped with a single RS422 output port can communicate with many antenna controllers). The Standard OMNI830BR satellite receiver can also accept commands via an RS422 serial port. It is possible for the OMNI830BR to be connected to an RS422 network which also includes RC1000 and RC2000 antenna controllers.

The following interconnect diagram shows the connections between a PC, the RC1KADP, the RC2000 (or RC1000) antenna controller, and the Standard Satellite receiver.

IBM PC		RC1KADP		RC2000 ANTENNA CONTROLLER	STANDARD RCVR--REMOTE
DB 25 25 PIN CONNECTOR	DB 9 9 PIN CONNECTOR	J1	J2	J3	CONTROL PORT
2	3	RXD	SHLD**		
3	2	TXD	RXD	4	6***
7	5	GROUND	/RXD	6	7
			TXD	3	4
			/TXD	9	8

** If the RS422 cable is shielded, the shield should be connected to the SHLD terminal of connector J2 of the RC1KADP.

*** For the OMNI830BR to communicate via the RS422 port, RS422 mode must be set via an internal jumper and the TTL mode must be set to OFF via the front panel.

6.2 RC1KADP Checkout Procedure

To verify the operation of the RC1KADP and PC serial port, a loopback test can be performed. To configure the RC1KADP for the loopback test, on connector J2 of the RC1KADP, connect RXD to TXD and /RXD to /TXD. During a loopback text, any character transmitted by the PC is received by the PC. Use the RC2K_.EXE program found on the diskette included with each antenna controller to send characters out of the serial port. The RC2K_.EXE program is documented in the README file found on the diskette.

Figure 6.1…Interconnect Diagram for Omni 830BR and RC2000 an a single serial connection

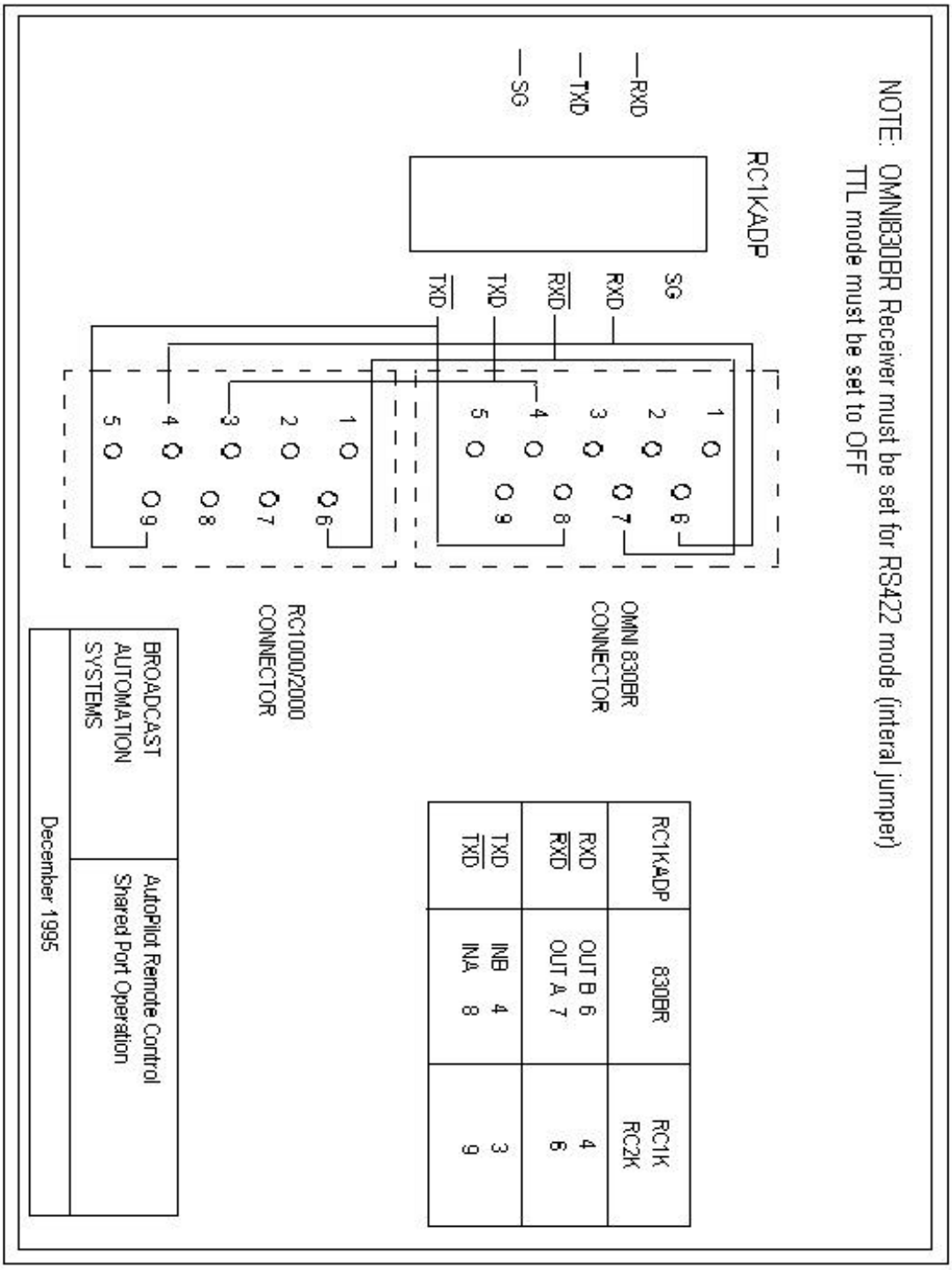

Figure 6.2…Schematic Diagram for the RC1KADP

6.3 Alternate Test Procedure for the RC1KADP

6.3.1 Test Procedure for RS485A1 Board (RC1KADP)

1. Clip lead TX1 to RX1 on terminal output strip
2. Clip lead TX2 to RX2 on terminal output strip.
3. Connect ground lead to power supply ground and voltmeter ground, then apply to pin on input terminal strip.
4. Apply 9V/200mA to J3 jack.
5. Monitor terminal TXD on J1 with red lead from voltmeter while applying and releasing 6-8VDC to terminal RXD on J1. Applying 6-8VDC to RXC should cause roughly a 9VDC level on TXD; removing the voltage should result in a –9VDC reading.

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v 1.11

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